Thermal conductivities of rice hull and ash combinations and its use as insulator for a gasifier reactor

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The growing abundance of rice hull is a continuing environmental concern. In the Philippines, approximately 2.5 million tons of rice hull were produced in 2000. There are already efforts to convert this waste material into useful products, more prominently as a source of energy. Determining the thermal conductivities of different rice hull and ash combinations can further widen its utilization by stimulating new ways and creativities. One of the potential applications for rice hull and ash would be not only as a fuel but as an insulating material for the small scale gasifier reactor. Using indigenous materials like rice hull and rice hull ash will significantly reduce the capital cost and the weight of the gasifier system. This can in turn improve the appropriateness and adaptability of the gasifier system for farming and rural communities of the Philippines.

Test materials

The thermal conductivities of rice hull, rice hull ash, and their mixtures were determined using two containers with varying thickness in three replications. The test material combinations were as follows: rice hull, compacted rice hull, rice hull ash, compacted rice hull ash, 50/50 mixture of rice hull and ash, and compacted 50/50 mixture of rice hull and ash. The rice hull derived from Indica varieties had moisture contents ranging from 10 to 13%. The bulk densities of test materials were measured as: 90, 216, 117, and 301 kg/m^3 for rice hull, compacted rice hull, rice hull ash, and compacted rice hull ash, respectively. Two containers with thickness of 10 and 15 cm were fabricated using the combination of BI sheet and wooden plate. An air space of 0.15 cm was provided between the heated plate and the container wall to prevent direct contact that may lead to test material combustion. A one-liter capacity gasoline fueled blowtorch was used for the heat source.

Thermal conductivities

The thermal conductivities K of test materials were determined using the simple heat conduction equation. The rates of heat transfer were based on the measured fuel consumption of the heat source and secondary data on the fuel's heating value. Analysis of variance on thermal conductivity values revealed significant effect of container thickness and highly significant variation among means on the kind of test material. The highest mean value was 5.00 W/m-K from compacted rice hull while the lowest mean value ranged from 4.55 to 4.65 W/m-K from the mixtures of rice hull and rice hull ash.

Comparison among means showed that generally the test materials had higher thermal conductivity values from the 10 cm container with average value of 4.92 than from the 15 cm container where the average value was 4.58 W/m-K. On the comparison among the different test materials, the highest thermal conductivity values were obtained from both loose and compacted rice hull while the lowest values were from the 50/50 mixture of rice hull and ash and from compacted rice hull ash with values of 4.55 and 4.65, respectively.

Results showed that rice hull ash is a better thermal insulator than rice hull. Furthermore, by compacting thereby decreasing the percentage of void spaces in the bulk of material, the thermal conductivity significantly increased for rice hull and the mixtures of hull and ash. The thermal conductivity of smaller particles rice hull ash was not significantly affected by the compaction.

Gasification application

The test material with the lowest mean thermal conductivity was the 50/50 mixture of rice hull and rice hull ash. This material was used as a lining for the reactor of a small-scale gasification system. The gasifier was based on the open-core downdraft type design from UC Davis which was introduced by PhilRice in selected farming areas of Central Luzon in the Philippines for pumping irrigation water. The system consists of a reactor with two concentric cylinders, a wet scrubber, two dry packed filters, a gasoline engine, and centrifugal water pump. The reactor was made from used oil drum and rolled BI sheets with diameters 40 cm for the innermost cylinder and 56 cm for the outermost cylinder. Both cylinders were lined with 2.5 cm thick 50/50 mixture of rice hull and ash covered by another layer of rolled BI sheet. The gasifer set-up was used to fuel a 10 hp gasoline engine coupled with a 5 cm centrifugal water pump.

Series of tests showed that the performance of the new set-up using the indigenous material for lining was not significantly different from the original set-up with concrete lining. The average consumption rate for rice hull was 8.8 kg/hr or equivalent to specific gasification rate of 71 kg/h-m^2. The average discharge from the pump was 11600 lit/hr with average engine rpm of 2054. Gasoline was needed during starting period and during the practiced five-minute engine run before and after using the gasifier for better engine maintenance. The average gasoline consumption was 0.23 lit/hr. Monitored temperature at the surface of the reactor was also comparable with concrete lined reactor. In most of the tests, the flow rate of water in the gas scrubber was maintained at an average of 480 lit/hr. This rate enabled the reduction of temperature of 116 ?C at the reactor outlet down to 38 ?C before it reached the engine.

Conclusion

There is an urgent need to utilize rice hull in as many forms as possible. Piles of rice hull are alarmingly increasing in most rice growing regions of the country posing environmental hazard. Knowing the many properties of rice hull and rice hull ash, particularly the thermal conductivity of the bulk of material can stimulate creativities leading to new utilization strategies. Using the rice hull and ash as lining material for gasifier reactor is one of the many possible applications. Gathered data showed that the 50/50 mixture of rice hull and rice hull ash with thermal conductivity of 4.55 W/m-K and the compacted rice hull ash with thermal conductivity of 4.65 W/m-K can be better thermal insulator than a loose rice hull. Gasification tests using the mixture of hull and ash for reactor lining proved feasible with its performance comparable with the use of concrete as lining. Using light and indigenous materials can make the gasifier easier to transport and assemble on farm, relatively cheaper, and more appropriate and adaptable in rural farming communities of the Philippines. With these findings, other ways of using the rice hull and rice hull ash, such as other insulating applications, can be developed.